

Optimized Algorithm for Fire Detection over WSN using Micaz Motes

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ABSTRACT

Environment degradation around the world has motivated many researchers to deal with an important yet endangering aspect of rural and forest fires. Most of the current developed technologies are based on detection of the fire rather than verifying it. Detecting the fire can be useful in many cases but it is still not efficiently implemented in real time systems. However, detecting fire systems can help many modern cities improve their smoke detection systems. Therefore, in this paper we introduce and implement a fire detecting algorithm built on measuring the temperature of a certain area and detecting the fire. We have also used a mathematical model called the “Acoustic ranging Technique” to detect the location and set the alarm in case of a fire. In our implementation we have used multiple MTS 300 sensor boards mounted on MICA2 motes, in order to sense the temperature of the fire with respect to the energy consumption. Hence, with use of the implemented algorithm, we can verify the size of the fire from temperature recorded and analyzed based on the color temperature. Finally, in this paper we could prove that the relation between the type of fire and its colors can be used in detecting the size of the fire efficiently.

1. INTRODUCTION

Several years ago, forest fires were a major issue that was a threat to the environment. Lately even civilized cities have started facing this problem. Not only the environment is harmed by the fires but also human beings suffer due to this. Especially during the summer seasons instates like California, each year thousands of houses are burned down and hundreds of people die of fire disasters. Therefore, pollution of water and environmental damage is resulted from the fire remnants. [8].

Furthermore, some natural resources can cause fire. In 2003, 45,000 people were evacuated and 239 houses were burned in Okanagan Mountain Park, Canada. The lightning and winds caused the spreading of fire around that forest. According to reports, this firestorm burned 25,912 hectares even though 1,000 fire fighters within 60 departments worked nonstop for long periods of time trying to stop it [2]. This was not the last firestorm that

was in that province. In 2006 more than \$156 million was spent on such disasters [3].

Fire detecting techniques based on wireless sensors has motivated many researches to improve and built early warning and better detection system. Sensors proved their efficiency in many monitoring systems. Sensors are used to detect and monitor a lot of natural and non-natural factors. With their ability of sending and receiving signals and data, sensors can determine and evaluate the type and speed of natural elements like fire, humidity, smoke, wind, etc., for example sensors in fire detectors [8]. These sensors send electrical signals between each other and notify the base station about the identified risk. Wireless sensor network (WSN) are defined as a network that include thousands of distributed nodes ‘sensors’ over the wireless links for the detection systems [1].

WSNs are used in many fields such as in industry of commerce and agriculture. Two factors are to be considered in WSNs. They are the limited in energy and have small memory [10]. However, in our implementation we use an efficient communication strategy to allow the closest sensor to receive the signal while others are asleep. Then send it to the central base station in order to reduce the power consumption. Therefore, WSNs can help the fire detecting systems by using these sensors to sense the fire type and its temperature.

The use of these wireless sensors in fire detecting systems help these sensors to send the alarm to the base station over the wireless links whenever the fire is detected. Based on that, the base station runs the application to determine the location, temperature and the size of the fire. This application can help the fire fighters or fire department to determine the size of the fire by the degree of the color based on the color temperature based database.

This paper organized as follows: the related work is described in section 2, the Ad Hoc Network design in section 3, overview of MICA2-MTS 310 sensor board and simulation setup in section 4, simulation results, and analysis in section 5 and conclusion in section 6.

2. RELATED WORK

There are limited fire detection systems that have been implemented and presented in literature. Most of these systems are only theoretical models rather than implementation. There is other multiple systems that are based on a single technique or on mixed techniques (e.g. mixed of multisensory and wireless cameras). However, in this section we have studied several proposed works which are related to our work.

The Forest Fire Surveillance system (FFSS) was improved by Son *et. al.* in order to overview South Korea Mountain [12]. This paper combined a web application, transceiver, WSN and middleware. The nodes used TinyOS as their operating system. The nodes collect the dimensions of the environment requirements such as humidity and temperature. The received node (Sink-node) sends these measurements to the software. Then the risk is determined by the middle ware software. Finally, the alarm is activated by FFSS for early warning of the fire.

In [5], the fire behavior is detected by Fire Wx Net. Fire Wx Net targets to measure the condition of the current weather and detect the visual data for both the base station as well as around the forest. These zone images are taken continuously. Hence, the natural factors such as temperature and wind speed should be measured by the system from time to time to determine the improvement of the risk. Also, the beauty of the system was that the team could prove that their system could be a realistic system for fire behavior analysis.

A new algorithm was introduced by Li *et. al.* in order to implement fire detection system for boreal zone in Canada [9]. The authors did not use only the satellite remote sensor in their system, but also they used the Advanced Very High Resolution Radiometer (AVHRR) to provide a high quality images around the fire. The system showed good features such as quick response and high quality of images for long distances.

Different from the systems presented earlier in this section, in [7] Wireless Local Area Network (WLAN) was used to determine the fire. The design in [7] is based on the verification of the fire rather than detect it. The improvement of this work is using the cameras and multi-sensor nodes. Hence, this system follows several steps to detect and verify the fire. Whenever a multi-sensor node detects the fire, the server receives the warning alarm over the network. The end user invokes the proposed application on the server to determine the closest camera easily. Lastly, the taken images are sent to the sink nodes. This system is used in real time.

A reliable framework is proposed in [4] for general reportage over the WSNs. The experiment shows that this general frame work can be used for fire detection. The developing team's focus is on the importance of circulation of detection systems. In order to reroute the data to the sink rapidly, the team introduces a new algorithm for collecting the data. The system filters the delayed - aware data as well as the significant data.

The presented techniques in this section have different features but lack the ability to specify the relation of the fire type and its temperature to its colors. In our new implementation presented in this paper, we show and elaborate how these factors can determine the size of the fire. Further, we are using MICA2 motes to sense the temperature of the fire and define its location using acoustic ranging.

3. PROPOSED WORK

3.1. Over view and experimental setup:

In this section we demonstrate the setup of our approach and the hardware features that support our deployment. Also, in this section we discuss several devices used in the proposed architecture. In our experimental tests, we use MTS300 sensor board. This board includes important modules such as sounder, thermometer, a Dual-Axis accelerometer (ADXL202), photon cell and Dual-Axis magnetometer [6]. However, the main components we use are the microphone, the sounder, the photon cell and thermometer to measure the temperature. Each component has a unique feature for our experimental tests and is explained in the following sub-sections.

A. Microphone circuit

Acoustic ranging and a general acoustic recording measurement are the two main functions in this circuit.

This circuit includes both a pre- amplifier (U1A-1) and second-stage amplifier with a digital-pot control (U1A-PT2). In acoustic recording and measurement principle the output of the low level of microphone is increased by preamplifier. With the help of an output selector (MX), the analog digital converter (ADC) can serve the output of microphone's low level. That can be done when the output selector links both ADC2 and mic_out signal. The storage devices of motes store the audio files. In second output, after the Tone Detector received the mic_out signal from filter (U), the analog microphone signal will be turned to the low or high level. The converted stage occurs usually when the tone becomes 4 kHz. This Tone will be generated on the board later by the sounder [11].

B. The Sounder

The sounder is a simple frequency with a range of 4KHZ. It includes both frequency and drive control circuitry. The

power switch is the only device that can control this sounder's operation.

C. The Light and Temperature Sensors

A/D converter channel (ADC) is the shared channel for the light and the temperature sensors as shown in Figure 1. It has a circuitry which allows only one sensor to work at a time [11]. The Cdse Photo is the light sensor. There are two conditions for this sensor that is a dark and a light condition. The digital control signal has to be on to use this sensor. ADC is always connected to the light sensor output in order to know the condition of the sensor.

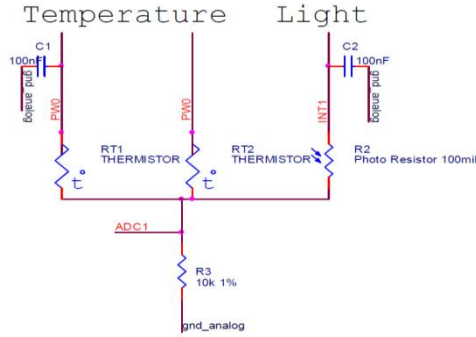


Figure1:The power controlled signal of MTS300 for Temperature and Light sensors.

The main focus of our application is to apply the acoustic ranging principle for tone detector and sounder sensor. Our experiment shows that both RF packet and radio signal are sent at the same time. By setting a counter on the timer on mote's process, it can receive RF packet and start to listen for the tone at the same time. Also, the beauty of this application is that, we can detect the fire location easily. This is done by increasing the counter until the microphone on the base station detects the tone produced by the sensor that detected the fire. This way we can calculate the time of flight of the sound and thus comparatively localize the location of the fire even though the wireless nodes are distributed randomly.

3.2. The Work Process and System Architecture

In this section we explain the procedure and the flow of our experiment as shown as in Figure 2.

Before initializing the master node, all the nodes are randomly distributed over the simulation area including the master node as shown in Figure 3. Figure 3 shows the architecture of the system and how the communication is done between the nodes and the master node as well as between the master node and the base station. Since the distribution is random, there is no known location of the nodes. However, an experimental area can include close to 1000 nodes and 200 master nodes. During the

simulation and placement of the nodes, some nodes are specific for sending the RF packet to the master nodes by the activation of the light sensor.

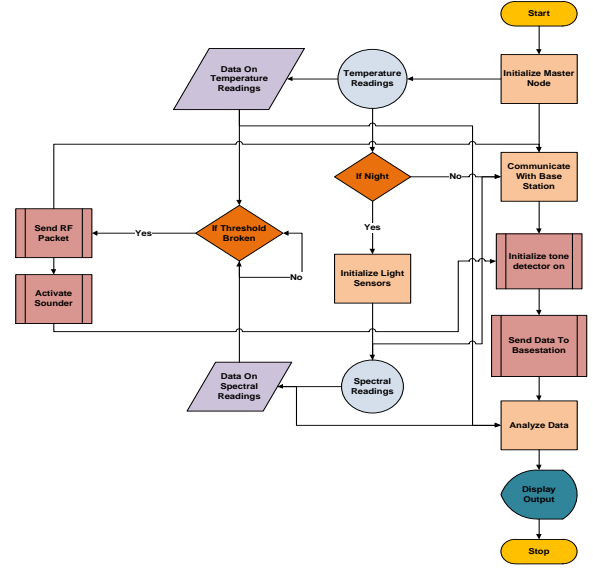


Figure 2: MTS300 Fire Detection system flow chart

Other nodes are specific to activate the sounder whenever fire is detected or the temperature threshold is broken.

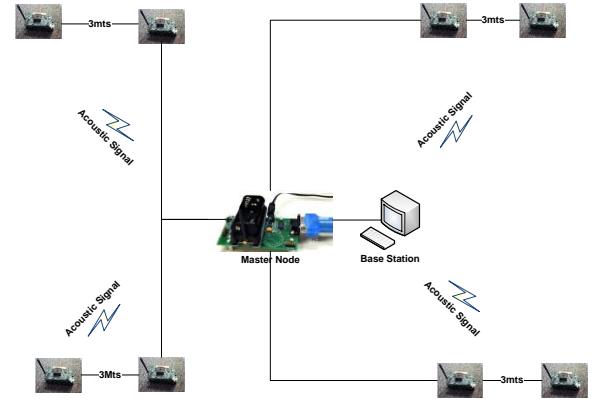


Figure 3: The System Architecture

Each node has its own module for sensing, (each MTS 300 panels committed to 2 separate MICAZ panels). Each sensor components has a separate sensor boards (each of the MTS 300 boards accomplish a separate task), and a light sensor is used by one board to detect the fire while the other measures the temperature and sets up the sounder (the fire is detected by the cdse photo cell).

Whenever, any light sensor of the node detects the fire, then its parallel sensor has to activate the sounder by sending an acoustic signal if the threshold of the temperature is broken. The detected node will send the RF packet to the master node.

According to the acoustic ranging principle, the counter of master node has to be reset as soon as the node receives the RF packet. To allocate the fire place we have to calculate the time of flight of the sound signal by the sounder. It is calculated based on the time that took of the master node's microphone to receive the sound signal. This approach is one of the easiest and non-expensive ways to allocate the fire without having a prior knowledge of the location of the node or acknowledgement from the detected node about the fire's location.

3.3 Methodology

In our experimental tests we use MICA2 motes. The model we use is MPR400CB and the data radio is CC1000900mhz. Hence, the MTS300 CA is used in order to extent the sound, temperature and light sensors. The proposed frame work involves programming the motes for permitting them to communicate with the master node and allow the master node to communicate with base station. The sensors send the readable data to the base station. The data describes the increase in the temperature of the fire as shown in our implementation in Figure 4. Based on our study we found that there is a relation between the fire's temperature and their colors. It is shown below whenever the temperature increases the color changes in several gradients. That can help us in detecting the size of the fire based on its colors.

1. Red: as the temperature increases, the redness changes until it reach the cherry color before it changes to next case.

- Observable: 980 °F (525 °C).
- Bright: 1,300 °F (700 °C).
- Cherry, bright: 1,500 °F (800 °C).
- Cherry, full: 1,700 °F (900 °C).
- Cherry, pure: 1,800 °F (1,000 °C).

2. Orange:

- Deep: 2,000 °F (1,100 °C).
- Pure: 2,200 °F (1,200 °C).

3. White

- Whitish: 2,400 °F (1,300 °C).
- Cheerful: 2,600 °F (1,400 °C).
- Impressive: 2,700 °F (1,500 °C).

In section 4 we discuss the results of our implementation and how with higher temperature and lower resistance of CKT we can get correct data.

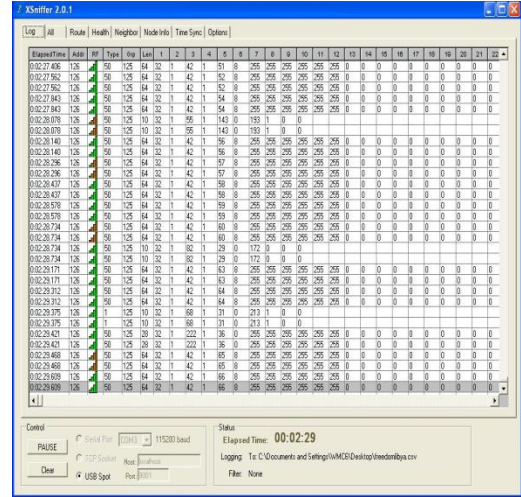


Figure 4: measured data of temperature of the fire is giving by several detected sensors

4. ANALYSIS THE RESULTS

As shown in section 3, we have used the MTS300CA sensor. MTS300CA helps in monitoring the energy of the fire and detects it as it moves around. The more fire spread around, the more nodes become active to detect the fire.

A. The relation between the measured temperature and the accuracy data scenario:

The complete Fire Detection system is implemented in NES C in UNIX Tiny OS platform or its equivalent Cygwin on a windows platform. A standard MEMSIC sensor board the MTS 300 mounted on top of the MICA2 was used for communication. An MIB 510 Program board issued to program the individual motes. The experimental results are conducted on a Pentium 2.4GHz computer system.

Figure 5 shows the relation between the resistances in the board to the temperature. By examining Figure 5, we can conclude that the temperature increases as the resistance decreases which lead to the accuracy of the measurements in temperature. The Cdse Photon sensors of the MTS 300 boards works as the primary detector in the initial detection of fire because factors like extreme sunlight or artificial light can confuse the photo sensor the thermistor of MTS300 takes care of the secondary measurement of temperature. Although the motes work perfectly individually, in order to cover a large area it is required to have multiple motes communicating with each other. As the distribution of motes is random we use the acoustic ranging technique which allows the motes to define its location to the base station.

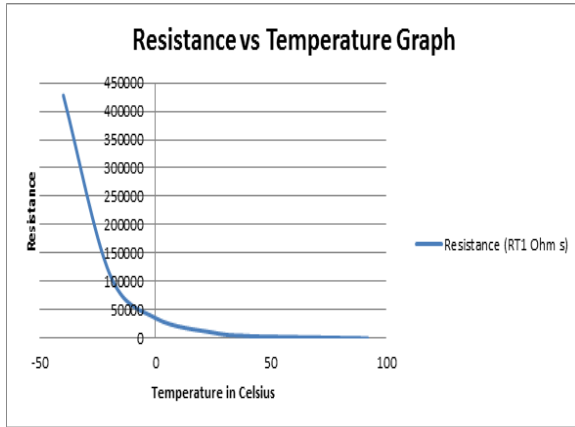


Figure 5: Resistance VS Temperature Graph

To evaluate the performance of our proposed Fire Detection system, a number of scenarios were created using up to 4 pairs of motes (8 modules) to conduct our experiment. We measure the intensity of light that allows the data base to confirm the type of fire especially the size based on the temperature inputs. The detection rate is the ratio of successful attempts (cases where the best detection is the correct detection) to the total attempts.

The results show that the detection rate is 92 % (increase in number of motes might provide better results). This makes our technique very suitable for many fire detection applications.

B. Power Consumption Scenario:

Figure 6 shows the behavior of power consumption of the sensors. Since the biggest issue in the wireless sensor networks is the energy consumption especially when there is random distribution of the sensors, it will be difficult to detect the sensor location to recharge in case the nodes run out of power. However, our results show that we can save in energy consumption of the sensor with our new algorithm. Since the experimental tests are based on activating several sensors which in and around the fire while the sensors are asleep, only the closest node will be active to detect the fire and inform the base station. When the detected node informs the base station, base station will send a signal back to all the nodes in the base stations vicinity for accepting all the readable data.

We also use the thermistor to measure the temperature. The measured temperature is retransmitted to the base station. With the use of the radio channel of the MTS300 we can send warning alarm to other nodes. Finally in Figure 6 it is clear to see more temperature data was recorded when more power was consumed.

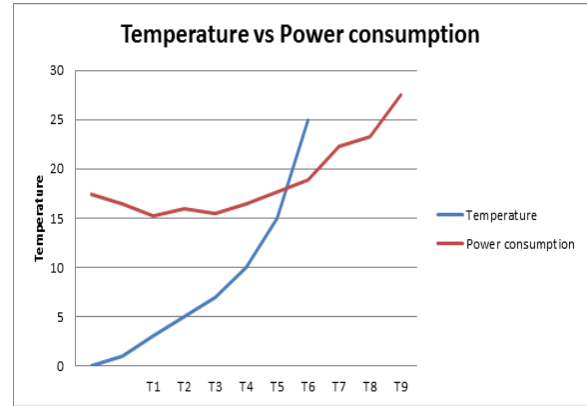


Figure 6: the behavior of the power consumption Vs the temperature

5. CONCLUSION

Fire detection has been used in many applications such as Forest fire Prevention systems, surveillance of volatile labs, etc. In this paper, we have proposed a new technique that implements a new fire detection algorithm. We have used MTS300CA that shows a high ability of monitoring in the MANET areas. The approach is fast, easy, and it provides a practical solution to the detection problem for either accuracy of data or power consumption. The system has a success rate of 92% for a large set of scenarios. Our implementation could prove high result not only in detecting the fire but also in verifying the fire location specifically.

This work is extended in the by using the IMB400 multimedia boards and using filtering mechanisms and computer vision technology to improve the accuracy of detection as well as the exact location of the fire.

REFERENCES

- [1] Ahmad Abed Alhameed Alkhatib and Gurvinder Singh Baicher, "An Overview of Wireless Sensor Networks", 2012 International Conference on Computer Networks and Communication Systems (CNCs 2012), 2012.
- [2] B.C. Ministry of Forests and Range. Fire Review Summary for Okanagan Mountain Fire (K50628).
- [3] B.C. Ministry of Forests and Range Web Page, <http://www.for.gov.bc.ca>.
- [4] E. Ngai, Y. Zhou, M. Lyu, J. Liu, "A Delay-aware Reliable Event Reporting Framework for Wireless Sensor-actuator Networks, Ad Hoc Networks," Vol. 8, Issue 7, pp. 694-707, 2010 Sdf.
- [5] Hartung, C.; Han, R.; Seielstad, C.; Holbrook, S. "Fire WxNet: a multi-tiered portable wireless system for monitoring weather conditions in wild land fire environments," In ACM, 4th International Conference on Mobile Systems, Applications and Services, Uppsala, Sweden, June 19-22, 2006.

- [6]<http://bullseye.xbow.com:81/Products/productdetails.aspx?sid=177>.
- [7] J. Lloret, M. Garcia, D. Bri, S. Sendra, A Wireless Sensor Network Deployment for Rural and Forest Fire detection and verification, sensor Nodes, Vol. 9 , Issue Detection and Verification, Sensor Nodes, Vol. 9, Issue 11, pp. 8722-8747, 2009.
- [8] Jaime Lloret, Miguel Garcia, Diana Bri and Sandra Sendra, "A Wireless Sensor Network Deployment for Rural and Forest Fire Detection and Verification", sensors ,2009.
- [9] Li, Z.; Nadon, S.; Cihlar, J. Satellite-based detection of Canadian boreal forest fires: development and application of the algorithm. Int. J. Remote Sens. 2000, 21, 3057–3069.
- [10] Mohamed Hefeeda and MajidBagheri, "Wireless Sensor Networks for Early Detection of Forest Fires ", Mobile Adhoc and Sensor Systems, 2007.MASS 2007.IEEE International Conference on, 2007.
- [11] MTS/MDA Sensor Board User'sManual, June 2006, PN: 7430-0020-04.
- [12] Son, B.; Her, Y.; Kim, J. "A design and implementation of forest-fires surveillance system based on wireless sensor networks for South Korea Mountains," IJCSNS 2006, 6, 124-130.